UNITED STATES AIR FORCE
AIRCRAFT ACCIDENT INVESTIGATION
BOARD REPORT

B-1B, T/N 85-0089

7TH AIRCRAFT MAINTENANCE SQUADRON
7TH BOMB WING
DYESS AIR FORCE BASE, TEXAS

LOCATION: DYESS AIR FORCE BASE, TEXAS

DATE OF ACCIDENT: 20 APRIL 2022

BOARD PRESIDENT: COLONEL TOBIAS B. SWITZER

Conducted IAW Air Force Instruction 51-307

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE GLOBAL STRIKE COMMAND

DEC 1 9 2022

ACTION OF THE CONVENING AUTHORITY

The report of the accident investigation board, conducted under the provisions of AFI 51-307, that investigated the 20 April 2022 mishap near Dyess AFB, TX, involving a B-1, T/N 85-0089, assigned to the 7th Aircraft Maintenance Squadron, substantially complies with the applicable regulatory and statutory guidance and on that basis is approved.

THOMAS A. BUSSIERE
General, USAF
Commander

EXECUTIVE SUMMARY
UNITED STATES AIR FORCE
AIRCRAFT ACCIDENT INVESTIGATION

B-1B, T/N 85-0089
DYESS AIR FORCE BASE, TEXAS
20 APRIL 2022

On 20 April 2022, at approximately 2216 local time (L), the Mishap Aircraft (MA), a USAF B-1B, tail number 85-0089, assigned to Dyess Air Force Base, 7th Bomb Wing, 7th Maintenance Group, 7th Aircraft Maintenance Squadron, experienced a catastrophic engine failure and fire on the #1 engine while undergoing maintenance on the main ramp at Dyess AFB, Texas. The MA suffered catastrophic damage to the #1 engine, as well as extensive fire damage to the left nacelle and wing. Debris from the explosion struck one Airman who suffered minor injuries and was treated promptly at the local hospital. The estimated cost of damage sustained by the MA is $14,943,680.00.

Shortly before the accident, the Mishap Maintenance Crew (MMC), comprised of members from the 7th Aircraft Maintenance Squadron and the 489th Aircraft Maintenance Squadron, performed routine corrective maintenance, in accordance with technical orders, in response to the MA's malfunctioning #1 engine variable area exhaust nozzle. During run-up to maximum augmenter to verify correct performance of the #1 engine variable area exhaust nozzle, the #1 engine catastrophically failed, ejecting its 2nd Stage Fan Disk from the intake section and severing fuel lines, which caused a fire to erupt in the engine. The 2nd Stage Fan Disk continued to fly away from the aircraft and landed over five hundred feet from the MA. The MMC executed emergency engine shutdown procedures and egressed away from the aircraft. Emergency crews quickly responded and extinguished the fire within ten minutes.

The Accident Investigation Board President found by a preponderance of the evidence that high cycle fatigue on the #1 engine's 2nd Stage Fan Disk was the cause of the accident. Laboratory testing demonstrated that high cycle fatigue initiated a crack on the surface of the 2nd Stage Fan Disk at the corner of a blade slot and the forward face of the disk. The crack, once initiated by the stress induced from repeated acceleration and deceleration of the engine, was propagated by a mix of high cycle and low cycle fatigue. The crack and its initial growth increased the stress beyond the 2nd Stage Fan Disk's yield strength, leaving it susceptible to low cycle fatigue. The surface crack grew to a depth of approximately 0.7 inches before the 2nd Stage Fan Disk broke apart causing the #1 engine to fail catastrophically. The root cause of the high cycle fatigue that caused the initial crack in the 2nd Stage Fan Disk could not be determined. No factors substantially contributed to this mishap.

Under 10 U.S.C. § 2254(d) the opinion of the accident investigator as to the cause of, or the factors contributing to, the accident set forth in the accident investigation report, if any, may not be considered as evidence in any civil or criminal proceeding arising from the accident, nor may such information be considered an admission of liability by the United States or by any person referred to in those conclusions or statements.

ACRONYMS AND ABBREVIATIONS

7 BW	7th Bomb Wing
AFB	Air Force Base
AFE	Air Flight Equipment
AFFH	Augmenter Fuel Filter Housing
AFGSC	Air Force Global Strike Command
AFI	Air Force Instruction
AFLCMC	Air Force Life Cycle Management Center
AIB	Accident Investigation Board
AMU	Aircraft Maintenance Unit
AMXS	Aircraft Maintenance Squadron
BP	Board President
Capt	Captain
CEF	Civil Engineering Firefighters
CES	Civil Engineering Squadron
CITS	Central Integrated Test System
CRF	Centralized Repair Facility
Col	Colonel
DEC	Digital Engine Computer
DoD	Department of Defense
DS	Day Shift
ERRC	Engine Regional Repair Center
ft	Feet
HPO	Hourly Post Flight
IAW	In Accordance With
IP	Instructor Pilot
IWSO	Instructor Weapons System Officer
JAA	Jet Fuel Grade A
LA	Louisiana
LRU	Line Replaceable Units
MA	Mishap Aircraft
MAJCOM	Major Command
MC	Mission Capable
MEC	Main Engine Control
MOC	Maintenance Operations Center
MM	Mishap Maintainer
MMC	Mishap Maintenance Crew
NC3	Nuclear Command and Control
NMC	Non-Mission Capable
OB	Observer
PSI	Pounds Per Square Inch
SD	South Dakota
SLEP	Service Life Extension Program
SOF	Supervisor of Flying
TAC	Total Accumulated Cycle
TAF	Terminal Aerodrome Forecast
TCTO	Time Compliance Technical Order
T/N	Tail Number
TX	Texas
Z	Zulu

SUMMARY OF FACTS

1. AUTHORITY AND PURPOSE

a. Authority

On 31 May 2022, General Anthony J. Cotton, Commander, Air Force Global Strike Command (AFGSC), appointed Colonel Tobias B. Switzer to conduct an Accident Investigation Board for a mishap that occurred on 20 April 2022 involving a B-1B aircraft, tail number (T/N) 85-0089 at Dyess Air Force Base (AFB), Texas (TX) (Tab Y-2). The aircraft accident investigation was conducted in accordance with (IAW) Air Force Instruction (AFI) 51-307, *Aerospace and Ground Accident Investigations*, at Dyess AFB, TX, from 8 June 2022 to 31 Oct 2022. The board members included a Rated Member (Captain), a Legal Advisor (Captain), a Maintenance Member (Master Sergeant) and a Recorder (Staff Sergeant) (Tab Y-2).

b. Purpose

In accordance with AFI 51-307, *Aerospace and Ground Accident Investigations*, this accident investigation board conducted a legal investigation to inquire into all the facts and circumstances surrounding this Air Force aerospace accident, prepare a publicly-releasable report, and obtain and preserve all available evidence for use in litigation, claims, disciplinary action, and adverse administrative action.

2. ACCIDENT SUMMARY

On 20 April 2022, at approximately 2216 local time (L), the Mishap Aircraft (MA), a USAF B-1B, T/N 85-0089, experienced a catastrophic engine failure and fire while undergoing maintenance on the main ramp at Dyess AFB, TX (Tab O-2). Mishap Maintainers 1 through 6 (MM1 – MM6), also referred to collectively as the Mishap Maintenance Crew (MMC), were performing an engine run on the Mishap Aircraft (MA) at the time of the incident (Tab R-10 and R-73). The MA suffered catastrophic damage to the #1 engine, as well as extensive fire damage to the left nacelle and wing (Tab J-3 to J-4). Hot shrapnel from the engine failure struck MM4 in the leg (Tab R-143). MM4's injuries included abrasions with lacerations, bone bruising, and muscle injury to the lower right leg (Tab DD-3). MM4 was treated promptly at the local hospital and put on quarters for one week (Tab DD-3). The cost of damage sustained by the MA is estimated at $14,943,680.00 (Tab P-2). MM1, MM2, MM4 and MM6 were assigned to the 7th Aircraft Maintenance Squadron (AMXS), and MM3 and MM5 were assigned to the 489th Bomb Group at Dyess AFB, TX (Tab V-3.1, V-5.1, V-11.1, V-12.1, V-14.1, and V-15.1).

3. BACKGROUND

a. Air Force Global Strike Command (AFGSC)

Air Force Global Strike Command (AFGSC), activated Aug. 7, 2009, is a major command with headquarters at Barksdale AFB, Louisiana (LA), in the Shreveport-Bossier City community. AFGSC is comprised of more than 33,700 Airmen and civilians responsible for the nation's three intercontinental ballistic missile wings, the Air Force's entire bomber force, to include B-52H, B-1B and B-2A wings, the Long-Range Strike Bomber program, Air Force Nuclear Command, Control and Communications (NC3) systems, and operational and maintenance support to organizations within the nuclear enterprise (Tab CC-2).

b. 7th Bomb Wing

The 7th Bomb Wing (7 BW) is the host unit at Dyess AFB, TX and is assigned to 8th Air Force at Barksdale AFB, LA. The wing hosts 13 units. The 7th Bomb Wing's mission is to provide world class Airmen and airpower for the warfighter. It is also charged with producing combat-ready aircrews in the Air Force's only B-1B formal training unit. Groups assigned to the wing include the 7th Operations Group, the 7th Maintenance Group, the 7th Mission Support Group, and the 7th Medical Group. In addition, the wing provides host-unit support for the 317th Airlift Wing and 489th Bomb Group also stationed at Dyess AFB, TX (Tab CC-5 and CC-6).

c. 7th Aircraft Maintenance Squadron

The 7th Aircraft Maintenance Squadron (7th AMXS), a subordinate unit of the 7th Bomb Wing, provides combat-ready B-1B aircraft and trained aircraft maintenance and weapons load personnel to support Joint Chiefs of Staff taskings for show of force missions and to destroy America's enemies—anytime, anywhere. It performs organizational-level maintenance of aircraft and armament subsystems. The unit also provides support for B-1B Formal Training Unit, Operational Test and Evaluation program and Weapons Instructor Course (Tab CC-6). The 9th Aircraft Maintenance Unit (9th AMU) is a sub-component of the 7th Aircraft Maintenance Squadron (Tab CC-14).

d. 489th Bomb Group

The 489th Bomb Group (489 BG) is a geographically separated unit with its headquarters, the 307th Bomb Wing, located at Barksdale AFB, LA. The 489 BG operates in a classic association with the 7th Bomb Wing at Dyess AFB, TX, flying the B-1B Lancer and overseeing three subordinate units: The 345th Bomb Squadron (345 BS), which operates in a classic association with the 9th Bomb Squadron, providing deployable combat aviators; the 489th

Maintenance Squadron (489 MXS), which operates in a classic association with the 7th Maintenance Group, launching and sustaining the fleet; and the 489th Aerospace Medicine Flight (489 AMDF), which ensures the medical readiness of the bomb group (Tab CC-9).

e. 489th Aircraft Maintenance Squadron

The 489th Maintenance Squadron (489th AMXS), a Total Force Associate (TFA) unit of the 7th Maintenance Group, provides combat-ready B-1B aircraft and trained aircraft maintenance personnel, weapons load personnel, and munitions personnel to support 7th Bomb Wing taskings (Tab CC-10).

f. B-1B Lancer

Carrying the largest payload of both guided and unguided weapons in the Air Force inventory, the multi-mission B-1B is the backbone of America's long-range bomber force. It can rapidly deliver massive quantities of precision and non-precision weapons against any adversary, anywhere in the world, at any time. It is operated at the 7th Bomb Wing at Dyess Air Force Base, TX, and by the 28th Bomb Wing at Ellsworth Air Force Base, South Dakota (SD) (Tab CC-3 and CC-6).

g. Engine Augmenter Run Maintenance Check

The B-1B is powered by four (4) General Electric F101-GE-102 engines (Tab BB-2). The engine is an augmented, mixed-flow, turbofan engine with a variable area exhaust nozzle. Each engine develops 15,000 pounds of non-augmented thrust and 30,000 pounds of thrust when augmented (Tab BB-2). Maintenance technical orders require augmenter testing after parts are replaced in the engine exhaust system in order to ensure proper performance of the engine (Tab BB-2). Maintenance technical orders require the following personnel for augmenter testing: an engine run supervisor to start the engine and operate throttles, a brake rider to ensure the aircraft does not move inadvertently, and a ground observer connected to the aircraft's intercom system (Tab BB-2).

Prior to engine maintenance operations, maintenance personnel performed a series of safety and preparatory steps in accordance with technical orders (Tab BB-2). These steps included the following: inspect inside and around the engine intake and exhaust areas for foreign object debris (Tab BB-2); install a set of chocks forward of each main landing gear truck (Tab BB-2); service the appropriate aircraft systems with gaseous nitrogen and engine oil (Tab BB-2); accomplish flight deck engine prestart checks (Tab BB-2); connect ground intercommunications (Tab BB-2); and perform fire warning extinguishing system operational check (Tab BB-2).

During engine maintenance operations, the engine run supervisor asks the ground observer for clearance any time he or she starts an engine or manipulates engine throttles (Tab BB-2). The engine run supervisor starts the auxiliary power unit(s) that will, in turn, start the aircraft engine(s) (Tab BB-2). The engine run supervisor contacts the Maintenance Operations Center (MOC) for permission to run engines and states the specific power settings that will be required (Tab BB-2). After receiving permission and before running engines, the engine run supervisor coordinates with the ground observer to ensure there are no personnel, vehicles, tools, or other foreign objects within the engine danger areas, after which the ground observer clears the engine run supervisor to start the engines (Tab BB-2). The brake rider sets the aircraft parking brakes, and the engine run supervisor proceeds to start the engines required for the appropriate operational checks (Tab BB-2). Once engines are started, the engine run supervisor waits five minutes before advancing any throttles for engine testing (Tab BB-2).

When an engine augmenter test is required, the ground observer ensures the engine danger areas are clear, then the engine run supervisor advances the throttle lever for the applicable engine to the desired power setting (Tab BB-2). Per maintenance technical orders, the augmenter will not be operated for more than ten seconds (Tab BB-2). As the engine accelerates, the engine run supervisor monitors engine instruments for any abnormal indications as well as any indications of a fire (Tab BB-2).

After corrective maintenance involving the engine exhaust nozzle, the engine run supervisor should observe the following engine exhaust nozzle indications as the engine throttle moves from idle to maximum augmenter.

Table 1 Engine Throttle and Exhaust Nozzle Co-Movement (Normal Operations) (Tab BB-2)

Engine Throttle Position	Engine Exhaust Nozzle Indications
Idle	99-101%
Intermediate	5-20%
Minimum Augmenter	10-20%
Maximum Augmenter	80% to Maximum Open Position

At idle speed, the engine exhaust nozzle is open to a range of 99% to 101% (Tab BB-2). As engine throttles advance to an intermediate power setting, the engine accelerates to its maximum core RPM, and the exhaust nozzle closes to a range of 5% to 20% open (Tab BB-2). When the throttle advances from intermediate power to minimum augmenter, fuel enters the engine augmenter section where it ignites for added thrust, and the nozzle opens slightly to a range of 10% to 20% open (Tab BB-2). When engine throttle advances from minimum augmenter to maximum augmenter, more fuel enters the engine augmenter section, and the exhaust nozzle opens to a range of 80%, its maximum open position (Tab BB-2). Once the engine run supervisor completes the operational check, they allow the engines to cool down at the idle setting for a period of five minutes prior to engine shutdown (Tab BB-2). After shutdown, the maintenance team services the aircraft systems and performs restoration follow-on maintenance (Tab BB-2).

4. SEQUENCE OF EVENTS

a. Mission

Not applicable.

b. Planning

Not applicable.

c. Preflight

Not applicable.

d. Impact

Not applicable.

e. Egress and Aircrew Flight Equipment

The MMC conducted emergency ground egress procedures without incident (Tab V-15.8). Ejection was not required and not attempted.

f. Search and Rescue

Not applicable.

g. Recovery of Remains

Not applicable.

h. Summary of Flight & Crew Change

Prior to the accident, the MA flew once on 20 April 2022 (Tab U-25). Aircrew from the 77th Weapons Squadron, using the call sign SLAM 1, took off at 1045L for a training sortie, landing back at Dyess AFB at 1402L (Tab U-25). SLAM 1 flew the MA for a duration of 3.1 hours (Tab D-10). SLAM 1 flew the MA at .75 Mach for most of the sortie duration, with a wing sweep of 25 degrees; the MA's augmenter was used only during takeoff, with minimal actuation in flight (Tab R-6). Upon completion of their sortie, SLAM 1 taxied the MA to Bravo 2 parking spot for refueling, and, with all engines running and functioning normally, turned over the MA to an aircrew from the 28th Bomb Squadron that intended to fly sortie call sign HAWK 81 (Tabs R-6 and U-25).

i. Hot Refueling Operations & Discovery of the #1 Engine Variable Area Exhaust Nozzle Malfunction

Upon taking control of the MA shortly after 1400L, the HAWK 81 aircrew shut down engines #3 and #4 and left engines #1 and #2 in idle (per 1B-1B-1 HOT REFUELING CHECKLIST) to begin the Hot Refueling Procedures (Tabs R-227 and BB-2). At 1449L, during refueling operations, the pilots of HAWK 81 observed that the nozzle position indication for the #1 engine variable area exhaust nozzle (hereafter referred to as #1 Nozzle) was in the closed position on the engine instrument panel when it should have indicated a fully opened position (Tab V-13.3). HAWK 81 completed refueling at 1457L (Tab K-3). The pilots of HAWK 81 then requested that the ground observer flag down propulsion specialists to assist them in investigating the #1 Nozzle malfunction (Tab V-13.3).

j. Maintenance Troubleshooting

Day shift propulsion specialists, dispatched to respond to the MA, discussed the malfunction with the crew of HAWK 81 and then began to diagnose the malfunction (Tab V-9.3). First, the propulsion specialists verified that the #1 Nozzle indicator on the engine instrument panel was functioning within its correct parameters and indications matched the physical position of the #1 Nozzle (Tab V-9.3). Next, the propulsion specialists asked the HAWK 81 pilots to advance the throttle for the #1 engine to intermediate power in order to see if the nozzle would actuate correctly (Tab V-6.3). When the HAWK 81 pilots moved the #1 engine throttle to intermediate power, the #1 Nozzle actuated within its specified operational parameters and returned to its correct open position when the throttle was returned to idle (Tab V-6.4). Satisfied that the issue had been resolved, the propulsion specialists departed the aircraft shortly before shift change at approximately 1530L (Tabs O-6, V-6.4, and V-13.5).

Soon after the propulsion specialists departed, and while the #1 engine remained in idle, the #1 Nozzle moved to the closed position on the engine instrument panel when it should have indicated a fully open position (Tab V-13.5). HAWK 81 notified the ground observer who flagged down the propulsion specialists. (Tab V-13.5). One of the previous propulsion specialists returned and verified the #1 Nozzle was physically closed to 20% when it should have been fully open (Tab R-259). The propulsion specialist speculated that a faulty thrust control unit or faulty thrust control actuator was the source of the malfunction and informed HAWK 81 that further troubleshooting would be required (Tab R-259). HAWK 81 decided to taxi the MA back to its original parking spot on Bravo 5 and fly their sortie with a different aircraft (Tab V-13.5 to V-13.6). At approximately 1600L, upon arrival at parking spot Bravo 5, HAWK 81 shut down the MA's engines (Tabs U-15 and V-13.5). The MA remained under the control of the 9th AMU for the remainder of the day through the time of the mishap at 2216L (Tabs O-2 and V-3.1 to V-3.2).

After the aircrew for HAWK 81 departed the MA, the 9th AMU crew chiefs performed a postflight inspection (Tab V-4.2). Postflight inspections consist of a visual inspection of the aircraft as well as system servicing to ensure serviceability and airworthiness of aircraft after each flight (Tab BB-2). As such, postflight inspections are separate from engine troubleshooting procedures (Tab BB-2). After the postflight inspection, MMC consulted the correct maintenance technical order series to rule out a thrust control actuator as the cause of the #1 Nozzle malfunction and correctly performed an operational check of the thrust control actuator. This operational check is performed with electrical power and cooling air applied to the aircraft without engines running (Tab BB-2). verifying throttle movement corresponded to correct thrust control actuation positioning (Tabs BB-2 and R-41). Using experience and system knowledge, MM1 concluded that the engine's hydraulic filter and hydraulic pump servo filter were the likely cause of the #1 Nozzle failure. (Tab V-15.9). Under MM1's direction, MM5 ordered a new engine hydraulic filter, rubber seals, and hydraulic pump servo filter, and then picked up the items from the supply warehouse (Tabs R-41, U-2 to U-4, and V-15.5-6). MM4 and MM5 replaced the #1 engine's hydraulic filters and hydraulic pump servo filter, and MM3 inspected the installation in accordance with Air Force technical orders (Tab BB-2 and V-5.8). According to technical data, the MA then required a maintenance Engine Augmenter Run procedure to check proper operations of the engine hydraulic pump and to ensure it did not leak fluid (Tab BB-2).

In preparation for the Engine Augmenter Run, MM1 inspected the #1 and #2 engine intakes and exhausts for foreign object debris (FOD) in accordance with maintenance technical orders (Tabs BB-2 and V-15.6). As part of this FOD check process described in the technical order, MM5 used a magnet bar to clear any metal particles located in the engine intake areas and performed a visual FOD inspection of the MA's parking area (Tab R-41 to R-42). Once MM5 ensured there was no FOD within the vicinity of the MA, MM1 performed a tool inventory to ensure all items were accounted for and secured (Tab V-3.3 and V-15.5). MM1 then proceeded to give a briefing to MM2, outlining his expectations of MM2 as brake rider for the Engine Augmenter Run procedure (Tab V-14.5 and V-15.6). At 2144L, MM1 called the MOC for approval to perform a maintenance engine run on two of the MA's engines at all power level settings (Tabs D-9 and V-15.6). As a general maintenance technique, maintenance personnel prefer to operate two engines at the same time because they provide more cooling air for the aircraft's avionics systems than a single engine (Tab BB-2). MM1 entered the MA's cockpit to prepare for the engine run (Tab V-15.6). MM2 entered the cockpit to serve as the brake rider (Tab V-14.3 to V-14.5). MM3 connected a ground intercommunication cable to the nose landing gear and served as the ground observer to observe for engine fires or any other abnormalities and to communicate with the engine run crew in the flight deck during the engine run (Tab V-5.3 and V-15.6). Prior to engine start, MM4 and MM5 positioned themselves near the aircraft's left-wing tip to observe the #1 Nozzle movements and used hand signals to communicate with the ground observer at the nose of the aircraft (Tab R-10 and R-54). MM6 was outside the aircraft, positioned between the left wing and the nose area to be able to observe the members of MMC at the wing tip and the nose (Tab R-10).

k. Engine Augmenter Run (#1 Engine)

At approximately 2144L, the MOC cleared the MMC to do an engine run for the MA (Tab D-9). Before MM1 started engines, MM2 properly set the parking brake (Tab V-15.6). MM1 started the Auxiliary Power Unit, the #1 engine, and then the #2 engine (Tab V-15.6). After properly allowing the engine to operate at idle for 5 minutes, MM1 advanced the throttle of the #1 engine into intermediate power setting and observed normal #1 Nozzle and engine indications on the engine panel (Tabs BB-2 and V-15.6 to V-15.7). MM6 positioned himself at a vantage point where he could clearly see the nozzle movement for the augmenter cycles (Tab V-3.5). While observing the #1 Nozzle from outside the MA, MM6 visually confirmed that the #1 Nozzle was functioning correctly and communicated this to MM1 through MM3 (Tab V-3.4). MM1 confirmed that the #1 engine indications were normal (Tab V-15.7). MM1 turned the #1 engine igniter switch to automatic to power on the augmenter ignitor, and then advanced the #1 throttle to maximum augmentation for no more than 10 seconds as specified in the maintenance technical orders (Tabs BB-2 and V-15.7). MM1 observed the green #1 engine augmenter light illuminate and the #1 nozzle position indicator displaying full open as expected and in accordance with maintenance technical orders (Tabs BB-2 and V-15.7). MM6 observed the #1 Nozzle fully open as expected and in accordance with maintenance technical orders and communicated this to MM1 through MM3 (Tabs BB-2 and V-3.4). MM1 moved the #1 throttle to idle and prepared to repeat the engine run sequence (Tab V-15.7).

l. Engine Failure

At approximately 2216L, MM1 advanced the #1 engine throttle from a stabilized idle power setting to intermediate power setting, and finally to the maximum augmenter power setting in accordance with maintenance technical orders (Tab V-15.7). MM1 noted that the #1 engine nozzle position indicator displayed that the nozzle was opening correctly as expected and in accordance with maintenance technical orders (Tabs BB-2 and V-15.7). All engine indications and performance were entirely within technical parameters throughout the engine's acceleration to maximum augmenter (Tabs BB-2 and V-15.7). MM6, positioned outside the aircraft, observed the #1 Nozzle opening (Tab V-3.3). Immediately after the #1 engine fuel flow augmenter flame detection light illuminated, a fire erupted from the left nacelle near the fan section of the #1 engine (Tabs S-50 and V-15.7). The ensuing fireball engulfed the entire left nacelle and proceeded outward along the left wing approximately 50 feet (Tab S-50). The fireball rose approximately 200 feet into the air and ejected parts of the engine and the cowling up to 1000 feet away (Tab S-28 to S-33 and S-50). MM1 witnessed no other abnormal indications from the other engines at the time of the incident (Tab V-15.14)

m. Shutdown and Egress

MM1 performed emergency engine shutdown and emergency ground egress procedures (Tab V-15.7 to V-15.8). In response to the fire at the #1 engine, MM3 directed the MMC to evacuate the MA and its vicinity (Tab V-15.7). MM2 began an emergency ground egress down the crew entry ladder while MM1 stayed to perform emergency firefighting procedures and notify the air traffic control tower (Tab V-15.7 to V-15.8). MM1 performed all emergency shutdown procedures correctly in accordance with maintenance technical orders (Tabs BB-2 and V-15.7). MM1 moved the #1 and #2 engine throttles to idle and moved the #1 and #2 engine start switches to the off position (Tab V-15.7 to V-15.8). MM1 then depressed the fire switch light for the #1 engine to engage the #1 engine fuel shutoff valve (Tab V-15.7 to V-15.8). Then, MM1 discharged the main and reserve fire extinguishing agent into the #1 engine (Tab V-15.7 to V-15.8). Next, MM1 shut down the left auxiliary power unit in accordance with maintenance technical orders (Tabs BB-2 and V-15.8). Finally, MM1 performed an emergency ground egress of the MA and evacuated with the rest of the MMC (Tab V-15.7 to V-15.8).

n. Incident Response

7 Civil Engineer Squadron (CES) Firefighters (CEF) received a report of an aircraft on fire on parking spot Bravo 5 at 2216L (Tab O-2). At 2218L the 7 CES/CEF dispatched four Aircraft Rescue and Firefighting vehicles and one fire engine vehicle (Tab O-3 to O-5). Shortly thereafter, firefighting assets arrived on scene at Bravo 5 and observed a fire in MA's #1 engine (Tab O-2). 7 CEF engaged the fire with remotely operated turrets (Tab O-2). At 2226L, the fire was extinguished by the on-scene firefighters (Tab O-2). The firefighting was conducted in accordance with procedures and there is no indication that firefighting efforts were delayed.

5. MAINTENANCE

a. Forms Documentation

The AIB reviewed the MA's active and recent Air Force Technical Order Forms 781s, historical jacket files, all available Integrated Maintenance Data System history, and Comprehensive Engine Management System records for accuracy, completeness, and compliance with applicable technical data and published guidance (Tabs BB-2 and D-10 to D-38). Several aircraft forms contain minor documentation errors (Tab D-21 to D-26). None of these discrepancies are relevant to the accident.

b. Inspections

MA's last preflight inspection was accomplished on 19 April 2022 at 1900L (Tab D-10). At the time of the incident, MA had accumulated 8,502.4 flight hours (Tab D-31). The MA's most recent Hourly Postflight Inspection was completed at 8413.6 flight hours (Tab D-33). The MA's last 800-hour Phase inspection was completed at 8213.6 flight hours (Tab D-34). MA's maintenance records contained no overdue special, calendar, hourly, or other required inspections (Tab D-33).

c. Maintenance Procedures

The AIB reviewed the maintenance inspections and tasks performed on the day of the incident (Tab D-10 to D-38). MM1 used his experience and system knowledge to diagnose two faulty engine hydraulic system filters as the cause of the exhaust nozzle failure (Tab V-15.9). Base supply warehouse records confirm that MM5 ordered and received a hydraulic filter and a hydraulic servo valve filter (Tab U-2 to U-4). MM5 replaced the engine hydraulic filters (Tab V-12.3). MM3 verified that MM5's work was in accordance with published technical orders (Tab V-5.8). Engine operational checks and maintenance actions were found to be in accordance with published aircraft technical orders (Tabs BB-2 and V-15.7 to V-15.8).

d. Maintenance Personnel and Supervision

MM1, MM4, and MM6 are propulsion specialists assigned to the 7th AMXS, 9th AMU (Tabs V-3.1, V-11.1, and V-15.1). MM2 is an electrical and environmental specialist assigned to the 7th AMXS/9th AMU (Tab V-14.1). MM3 and MM5 are propulsion specialists assigned to the 489th Maintenance Squadron (MXS) and were assisting 9th AMU (Tab V-5.1 and V-12.1). MM1 was a fully qualified engine run supervisor by virtue of having graduated an engine run class, passed a written examination, and certified during a practical evaluation by a qualified engine run certifier (Tab G-2 to G-26). MM1 was responsible for the operation of the MA engines during the accident and was positioned in the pilot's seat (Tab R-191 to R-192). MM2 was a qualified brake rider by virtue of having graduated engine run class and passed the written engine run exam (Tab G-27 to G-56). MM2 was positioned in the copilot's seat and was responsible for operating the aircraft's landing gear brake (Tab V-14.5). MM3 was the ground observer on intercom, positioned at the nose of the aircraft (Tab V-5.3). MM4 and MM5 were positioned at the left wingtip, observing the engine run (Tab R-10 and Tab R-54). MM6 was positioned between the left wing and the left side of the nose of the aircraft to observe the engine run (Tab R-10). Based on training records, all maintenance personnel present during the incident were fully qualified to perform the tasks they were performing (Tabs G-2 to G-197 and T-2 to T-69).

e. Fuel, Hydraulic, Oil, and Oxygen Inspection Analyses

Following the accident, the Air Force Petroleum Office (AFPET) analyzed fluid samples taken from the following fuel tanks of MA: 1B, 1C, 2A, 2B, 3B, 3C, 4, 5L, 5R, 6L, and 6R (Tab D-3, D-5, and D-7). AFPET determined that the fuel samples provided contained no detectable contaminants (Tab D-3, D-5, and D-8).

Additionally, the following post-accident samples were sent to the 76th Maintenance Support Squadron Analytical Chemistry Section at Tinker AFB for laboratory analysis: Jet Fuel Grade A (JAA) samples taken from the aircraft main fuel tank sump ports and the Main Engine Control (MEC); oil samples from the #1 engine oil tank and gearbox main drain; hydraulic fluid samples taken from aircraft hydraulic systems 1, 2, and 4; engine lube and scavenge oil filter, engine hydraulic filter, and pin filter (Tab U-5). The Laboratory Report stated there were no abnormal conditions present in any of the provided samples (Tab U-5 to U-10).

f. Unscheduled Maintenance

The AIB conducted a review of unscheduled maintenance performed on the Mishap Engine (ME). On 19 April 2021, the engine was removed from a B-1B assigned to Ellsworth AFB, SD, for a #4 bearing oil leak (Tab J-3). The ME was shipped to the Centralized Repair Facility (CRF) at Dyess AFB, TX, for repair (Tab J-3). On 27 January 2022, the ME was installed in the #1 position of the MA (Tab J-3). Engine component wear is measured by the amount of Total Accumulated Cycles (TAC) that the engine has experienced (Tab BB-2). TACs are determined by the number of times an engine has been accelerated and then decelerated (Tab BB-2). This measurement determines the inspection and overhaul requirements for the different engine components (Tab BB-2). TACs on a B-1 are calculated by the engine's Digital Engine Computer (DEC) (Tab BB-2). At the time of the accident, the ME's DEC reported 320 TACs since the ME's last overhaul in April 2017 and that it still had 3,680 TACs remaining until the next scheduled engine overhaul at 4,000 TACs (Tabs BB-2, EE-11, and U-27).

The history of the ME's 2nd Stage Fan Disk was also examined. In May 1988, the disk was first installed into an engine (Tab J-3). The 2nd State Fan Disk performed without issue until December 2002, when it was removed from the engine to have a time compliance modification performed (Tab J-3). The 2nd Stage Fan Disk sat unused until August 2003 when it was installed into another engine (Tab J-3). In May 2014, the 2nd Stage Fan Disk was damaged when its engine ingested an aluminum fastener, causing FOD damage to two of the 2nd Stage Fan Disk blades (Tab J-3). The 2nd Stage Fan Disk was repaired in accordance with technical order specifications at Dyess AFB at the Engine Regional Repair Center (ERRC) and returned to service as a spare asset (Tab J-3). The 2nd Stage Fan Disk received a modification to its dovetail slots by Air Force Life Cycle Management Center (AFLCMC) technicians as part of its Service Life Extension Program (SLEP) upgrade in January 2017 (Tab J-3). AFLCMC installed the modified 2nd Stage Fan Disk on the ME in April 2017 during the ME's SLEP modification and overhaul at Tinker AFB, OK (Tab J-

3). The ME served as a spare for two years until its installation in an aircraft in March 2019 (Tab J-3). In April 2021, the ME was removed for a #4 engine bearing oil leak (Tab J-3). In January 2022, the ME was installed in the #1 position of the MA, and it performed without any major issues until the mishap (Tab J-3). The #4 bearing performed as expected and was not relevant to the mishap (Tab J-6).

6. AIRFRAME, MISSILE, OR SPACE VEHICLE SYSTEMS

a. Structures and Systems

At the time of the mishap, the ME had a total of 7448.7 total flight hours with 12.2 flight hours since its last Hourly Postflight Inspection (HPO) (Tab D-33). After 101 hours engine operating time in the #1 position of MA, the accident occurred (Tab J-3).

During the accident, the ME's 2nd Stage Fan Disk was ejected (Tab J-3). The 2nd Stage Fan Disk was recovered with most of its fan blades stripped off (Tab J-7). The 2nd Stage Fan Disk was broken into three large sections and many smaller ones (Tab J-7). All significant sections of the disk were recovered (Tab J-7). The ejection of the 2nd Stage Fan Disk created a large hole in the outboard side of the ME and liberated many accessory components from the engine (Tab J-3). Post-fire investigation identified charring and burning on the left side of the aircraft (Tab J-3). The worst burn damage was focused on the mid-section of the ME (Tab J-3).

A teardown of the ME was performed by the AFLCMC at Dyess AFB following the mishap (Tab J-3 to J-7). AFLCMC F101/F118 engineers provided analyses based on the teardown findings, which indicated the following: the engine front frame suffered buckling failure (Tab J-4); the compressor section and turbine section suffered foreign object damage as a result of the 2nd Stage Fan Disk separating from the engine (Tab J-4); the FOD generated by the fan disk's ejection caused significant damage to the blades of the engine compressor (Tab J-4); compressor section blades showed indication of a titanium fire, with subsequent stages of blades and vanes largely destroyed (Tab J-4); approximately 2.5 inches of the low-pressure turbine shaft were missing from the engine (Tab J-5). Debris from the fan section was found inside the augmenter/exhaust nozzle of the engine (Tab J-5). Despite missing many components, the augmenter exhaust nozzle was cycled through by hand, and found to move freely without any binding (Tab J-5).

(1) #1 Engine

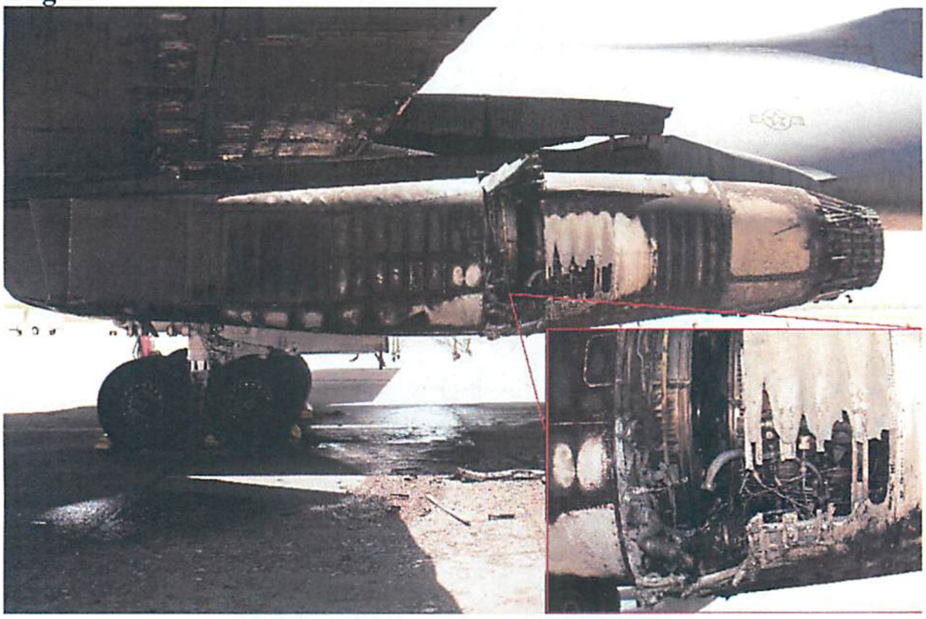

Figure 1. Engine Post-Accident (Tab Z-2)

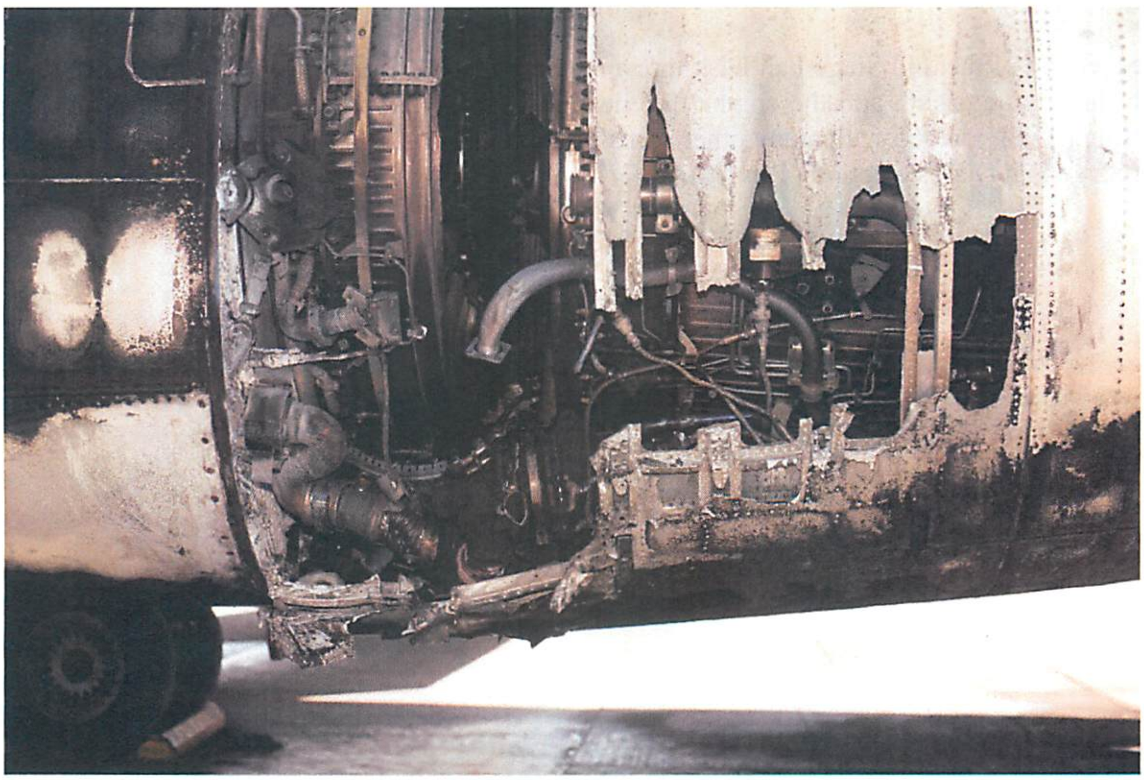

Figure 2. Engine Post-Accident (Tab S-21)

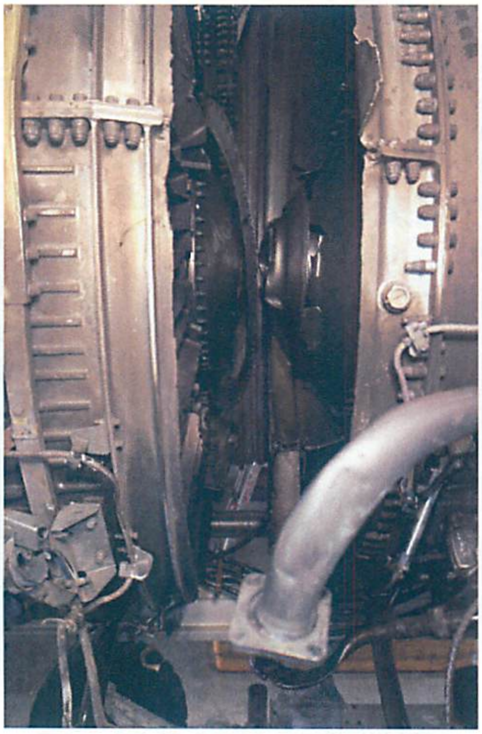

Figure 3. #1 Engine Fan Section Post Accident (Tab S-8)

The ejection of the 2nd Stage Fan Disk tore an approximately five-inch-wide strip of metal from both the engine casing and the engine nacelle skin (Tab J-4). The engine augmenter fuel filter housing (AFFH), along with many other accessory components, were torn from the engine by the 2nd Stage Fan Disk's ejection (Tab J-6).

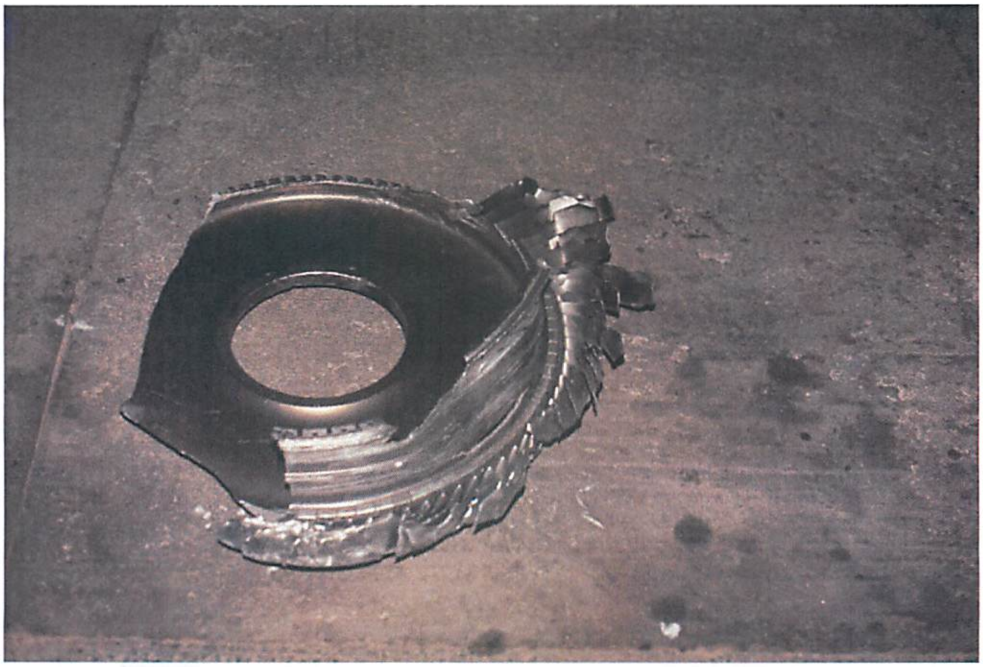

Figure 4. #2 Fan Disk (S-22)

The 2nd Stage Fan Disk was ejected from the #1 engine and found approximately 564 feet away from the aircraft, stripped of most of its fan blades (Tab Z-20).

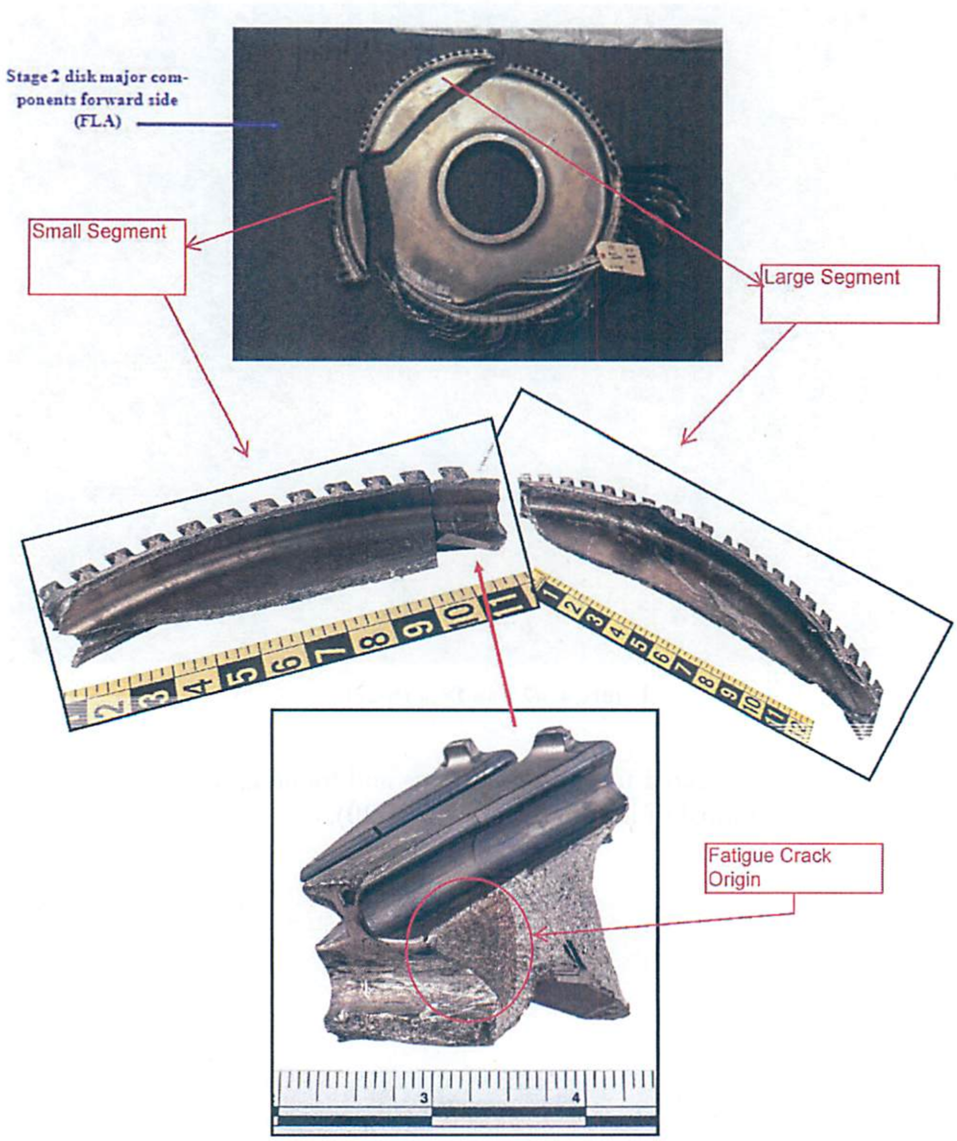

Figure 5. 2nd Stage Fan Disk Crack Origin (Tab Z-3)

The 2nd Stage Fan Disk was found broken into three large sections and many smaller ones (Tab J-7). All major sections of the fan disk were recovered (Tab J-7). Using a variety of laboratory techniques, technicians at AFLCMC were able to determine the exact point of the origin of the crack that led to the failure of the 2nd Stage Fan Disk (Tab EE-56).

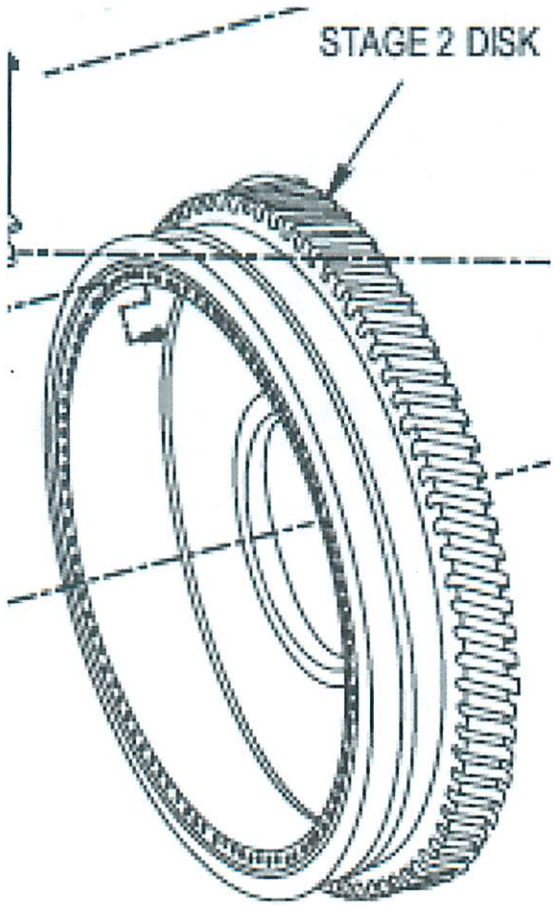

Figure 6. Technical Drawing of 2nd Stage Fan Disk (Tab Z-4)

This technical drawing displays an intact 2nd Stage Fan Disk (Tab Z-4).

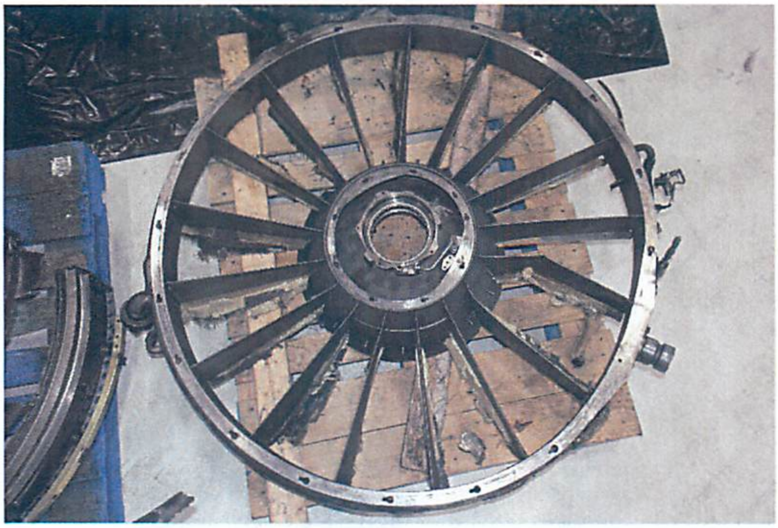

Figure 7. #1 Engine Inlet Guide Vanes Damage (Tab S-9)

The engine front frame suffered buckling failure (Tab J-4). The compressor section and turbine section suffered foreign object damage as a result of the 2nd Stage Fan Disk separating from the engine; this caused significant damage to the blades of the compressor and turbine section of the engine resulting in rounded compressor blades instead of the normal squared ones (Tab J-4 to J-7).

(2) Left Wing

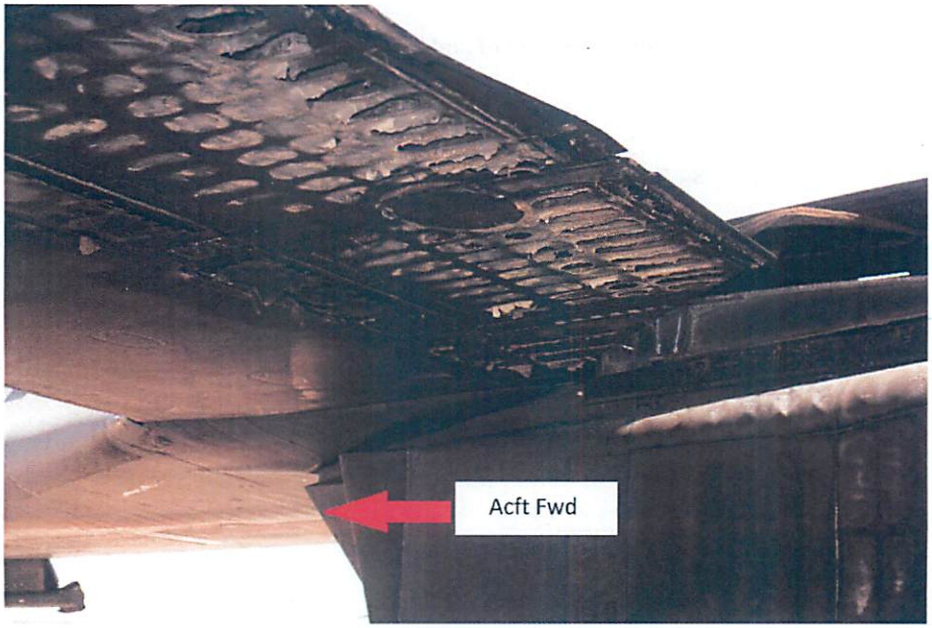

Figure 8. Left Wing Fire Damage (Tab Z-5)

Figure 9. Left Wing Underside Damage (Tab S-14)

As a result of the fire, the left wing suffered extensive surface level fire damage (Tab S-5 to S-6 and S-10 to S-18). The damage on the wing is most extensive near the wing root with the physical melting of the MA skin due to the intense heat from the fire (Tab S-5 to S-6 and S-10 to S-18).

(3) Left Nacelle

Figure 10. Left Nacelle Damage (Tab S-23)

The #1 Engine nacelle showed signs of fire damage, and metal components were peeled away from the nacelle structure by the ejection of the 2nd Stage Fan Disk (Tab J-3).

(4) Fuselage

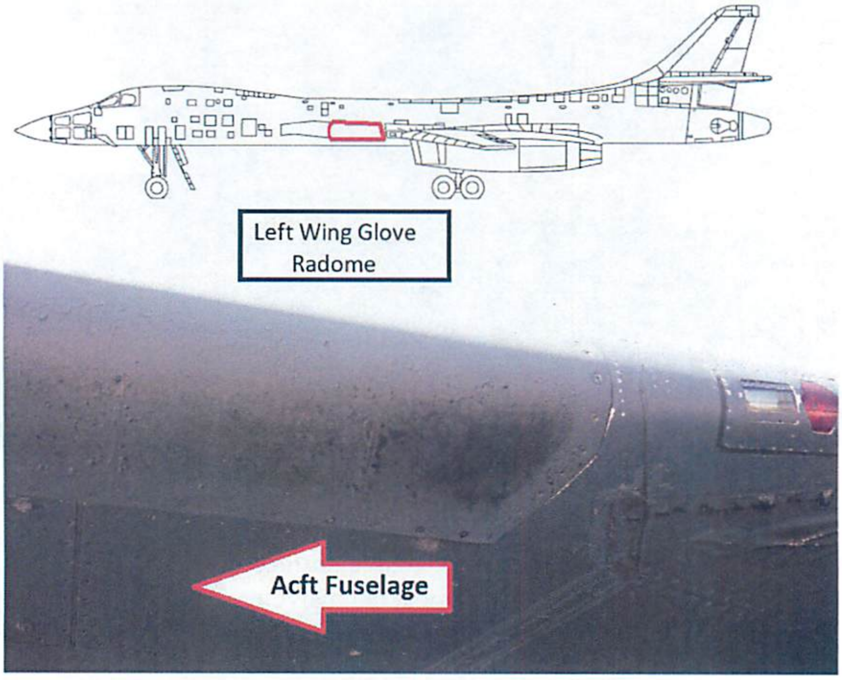

Figure 11. Left Wing Glove (Tab Z-6)

Heat damage from the fire extended forward to the left wing glove radome area, just forward of the left wing, blistering the paint (Tab J-3).

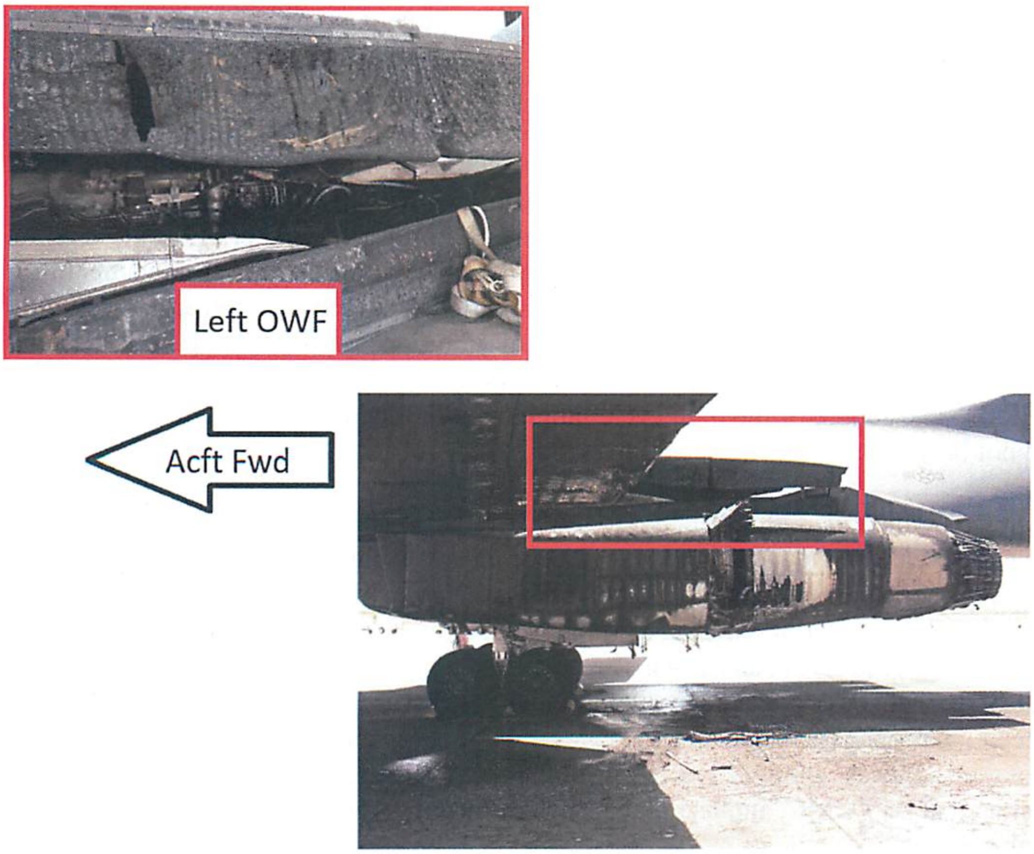

Figure 12. Left Overwing Fairing (Tab Z-7)

The engine fire reached the left overwing fairing (OWF), damaging numerous structures and components. The overwing fairing is part of the B-1's variable wing sweep design that allows for uninterrupted airflow over the wing of the B-1 when the wings are swept to an aft position (Tab BB-2). During high-speed flight, the aircrew manually position the wings to an aft position, where they are tucked inside the overwing fairing for improved aerodynamic performance (Tab BB-2). The overwing fairing also houses many critical mechanical, electrical, and hydraulic system components (Tab BB-2).

b. Evaluation and Analysis

(1) Air Force Lifecycle Management Center Failure Report

AFLCMC focused its engineering causal analysis on the MA's #1 engine 2nd Stage Fan Disk because its ejection from the engine case caused the subsequent catastrophic damage (Tab EE-8). The lab determined that the disk was manufactured from the correct titanium alloy and its construction met the correct metal hardness requirements (Tab EE-8 and EE-55). At the time of the mishap, the 2nd Stage Fan Disk had 6,181 TACs; the life expectancy set by the engineers is 25,000 TACs (Tab U-27). The fan disk still had 75.3% of its total life expectancy remaining (Tab U-27).

Using a variety of techniques, the lab was able to identify the origin of a crack that led to the disk's failure (Tab EE-8). The crack began at a single point on the disk's surface at the corner of a blade slot and the forward face of the disk (Tab EE-24 and EE-55 to EE-56). High cycle fatigue of an unknown origin initiated the crack on 2nd Stage Fan Disk (Tab EE-24 and EE-55 to EE-56). High cycle fatigue is a low-stress event that causes an engine component to deform within its elastic range during engine acceleration and return to its original form when the engine decelerates (Tab EE-4). High cycle fatigue occurs due to the heating and cooling of the material during engine acceleration and deceleration and is accounted for during the design of engine components (Tab EE-4). Abnormal engine vibrations can provide an additional source of high cycle fatigue; however, testing could not identify a source of abnormal vibrations on the ME (Tabs BB-2 and EE-55 to EE-56). High cycle fatigue is commonly found in rotating engine components such as a fan disk (Tab EE-4). The source of the high cycle fatigue that initiated the crack in the 2nd Stage Fan Disk could not be determined (Tab EE-56).

Laboratory testing demonstrated that the progression of the crack at or near its origin was consistent with high cycle fatigue; additionally, evidence of low cycle fatigue was found towards the end of the crack propagation (Tab EE-30). Low cycle fatigue is a high-stress event that exceeds the elastic strength of the material, causing permanent deformation and leading to component failure within a few engine cycles (Tab EE-4). The crack and its initial growth increased the stress beyond the 2nd Stage Fan Disk's elastic strength, which left it susceptible to low cycle fatigue (Tab EE-3). The crack propagated to an approximate depth of 0.7 inches before the 2nd Stage Fan Disk failed, broke into pieces, and was ejected from the ME (Tab EE-24). In addition, the ME's AFFH was examined at AFLCMC, and technicians determined that the AFFH was not relevant to the incident (Tab J-6).

(2) Digital Engine Computer

The Digital Engine Computer (DEC) of the F101 engine controls the engine's operation, stores parametric data about the engine's performance, operating time, total accumulated cycles (TACs), and records any faults (Tab BB-2), Members of the 7th Component Maintenance Squadron at Dyess AFB as well as AFLCMC accomplished a comprehensive review of all parametric engine sensor data recovered from the #1 engine DEC (Tabs U-12 and J-7). Although the computer data showed numerous engine faults, technicians concluded that the data was inconsistent and inconclusive as to whether the faults occurred prior to the engine explosion or were caused by the engine explosion (Tab U-12).

(3) Central Integrated Test System

The B-1 Lancer has a built-in self-testing system called the Central Integrated Test System (CITS) (Tab BB-2). CITS records the function of every system on the aircraft and records their performance and faults (Tab BB-2). Members of the 7th AMXS at Dyess AFB performed a comprehensive review of the parametric data recovered from the MA's CITS computer (Tab U-11). Technicians determined that all engine and aircraft systems were operating within their respective parameters leading up to the incident and were unable to identify any engine malfunctions prior to the failure (Tab U-11).

7. WEATHER

a. Forecast Weather

The local Terminal Aerodrome Forecast (TAF) was issued on 20 April 2022 at 1500L (Tab F-2). The weather forecast for Dyess AFB at 2200L was clear skies with unlimited visibility (Tab F-2). Winds were from the southwest (210) at 12 knots gusting to 18 knots (Tab F-2).

b. Observed Weather

The local weather at Dyess AFB at 2156L was clear skies, visibility of 10 statute miles, temperature 27 degrees Celsius, and winds from the south (170) at 10 knots (Tab F-2). The local weather at Dyess AFB at 2256L was clear skies, visibility of 10 statute miles, temperature of 26 degrees Celsius, and winds from the south (160) at 14 knots (Tab F-2).

c. Space Environment

Not Applicable.

d. Operations

The wind limitation for B-1B engine start and ground run is a tailwind component not exceeding 20 knots (Tab BB-2). Any time a tailwind component of 20 knots or greater is present, the aircraft must be towed to a new location to neutralize the tailwind component prior to engine start and ground run (Tab BB-2). The aircraft was parked with its nose oriented to 070 degrees (Tab Z-8). Based on the observed winds, the tailwind component was 0 knots (Tab F-2). There is no evidence to suggest that the observed weather or aircraft location exceeded technical order requirements for engine start and ground run.

8. CREW QUALIFICATIONS

MM1 through MM6 were qualified or were supervised by personnel qualified in the performance of the Change Fuel Filter, Thrust Control Actuator check, Inlet and Exhaust Inspections, and Engine Augmenter Run maintenance procedures (Tabs G-2 to G-197 and T-2 to T-69).

9. MEDICAL

a. Qualifications

All the members of the MMC were medically qualified for their duties as maintenance technicians without restriction (Tab DD-11). There is no evidence to suggest that medical qualifications were a factor in the mishap.

b. Health

There is no evidence to suggest that health was a factor in the mishap.

c. Pathology

Not applicable.

d. Lifestyle

There is no evidence to suggest lifestyle was a factor in the mishap.

e. Rest and Duty Time

There is no evidence to suggest that rest and duty time were factors in this mishap.

f. Toxicology

There is no evidence to suggest that toxic substances were a factor in the mishap.

10. OPERATIONS AND SUPERVISION

a. Operations

The 9th AMU organizes its work activity into three daily shifts: Days (0730-1630L), Swings (1530-0030L), and Mid-Shift (2330-0830L) (Tab O-6). The 7th MXG tracks multiple metrics that demonstrate the overall maintenance capability and workload of the group (Tab U-15 to U-25). During the week prior to the accident, the 9th AMU had executed 19 of 19 scheduled flights while maintaining a 67.7% average mission capable (MC) rate for the 7th BW's B-1B fleet (Tab U-17). During the week of the accident, the 9th AMU did not have any aircraft that were non-mission capable (NMC) status for discrepancies relating to engines (Tab U-20). Two days prior to the accident, the 9th AMU executed 8 of 8 scheduled flights with an 80% MC rate across the 7th BW (Tab U-21). One day prior to the accident, the 9th AMU executed 5 of 5 scheduled flights with a 70% MC rate across the 7th BW (Tab U-23). On the day of the accident, the 9th AMU executed 4 of 5 scheduled flights with a 66.6% MC rate across the 7th BW (Tab U-25). Overall, during the week of the accident, the 9th Bomb Squadron and the 9th AMU executed 27 of 28 scheduled flights with a 69.4% average MC rate for the 7th BW (Tab U-18).

The AIB reviewed the overall maintenance capability and workload of the 7th MXG and determined that the MMC's workload was normal on the night of the accident (Tab R-51, R-79, R-140, R-183, and R-207).

b. Supervision

On the night of the accident, Observer 1 (OB1) was the 9th AMU Expediter present on the flight line and was responsible for directing/supervising flightline maintenance actions and reporting aircraft status to MOC (Tab V-8.2 and V-8.4). At the time of the accident, he was observing a hot pit refuel on an aircraft near MA (Tab V-8.2). OB1 saw the failure and fire and immediately began directing maintainers off the flight line to a safe distance (Tab V-8.2). He drove his government vehicle (GOV) to the MA, picked up MM4, and drove him to safety (Tab V-5.4). The rest of the MMC ran to the 9th AMU building on foot (Tab V-5.4) Once MM4 was delivered to the building, OB1 drove his GOV back out to the flight line to check for any other maintainers (Tab V-8.2).

Based on the evidence, the AIB determined that the MMC had organized themselves based on experience and qualifications, rather than rank, for the engine run task on the night of the incident (Tab V-3.3, V-5.3, V-11.2, V-12.4, V-14.3, and V-15.6). MM1 served as engine run supervisor because he was the certified engine run maintainer on the MMC, despite being lower ranking than MM3 (ground observer) (Tabs V-5.3 and V-15.4).

11. HUMAN FACTORS ANALYSIS

The Department of Defense Human Factors Analysis and Classification System 7.0 (DoD HFACS 7.0) lists potential human factors that can play a role in aircraft mishaps and identifies potential areas of assessment during an accident investigation. There is no evidence to suggest that human factors were a factor in this mishap.

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Publicly Available Directives and Publications Relevant to the Mishap

(1) AFMAN 11-2B-1V3, *B-1 Operating Procedures*, 14 December 2020
(2) AFI 21-101, *Aircraft and Equipment Maintenance Management*, 16 January 2020 (incorporating corrective actions applied on 15 September 2020)
(3) AFI 21-101, *Aircraft and Equipment Maintenance Management* (AFGSC Supplement), 19 January 2021 (incorporating Change 2, 11 May 2022)
(4) AFI 21-101, *Aircraft and Equipment Maintenance Management* (Dyess AFB Supplement), 30 January 2019
(5) AFMAN 13-204V1, *Management of Airfield Operations*, 22 July 2020
(6) AFI 51-307, *Aerospace and Ground Accident Investigations*, 18 March 2019
(7) DAFI 91-204, *Safety Investigations and Reports*, 10 March 2021
(8) DAFMAN 91-233, *Aviation Safety Investigations and Reports*, 20 September 2022
(9) Department of Defense Human Factors Analysis and Classification System 7.0 (DoD HFACS 7.0), available at https://www.safety.af.mil/Divisions/Human-Factors-Division/HFACS/

(10) DODI 6055.07, *Mishap Notification, Investigation, Reporting and Record Keeping* (6 June 2011 Incorporating Change 1, 31 August 2018)

NOTICE: Unless otherwise noted, all directives and publications listed above are available digitally on the Air Force Departmental Publishing Office website at: https://www.epublishing.af.mil.

b. Other Directives and Publications Relevant to the Mishap not Publicly Available

(1) 00-20-1, *Aerospace Equipment Maintenance Inspection Documentation Policies and Procedures*, 21 June 2021
(2) 00-20-2, *Maintenance Data Collection*, 22 July 2021
(3) 1B-1B-2-00GV-1, *General System*, 01 Aug 2022
(4) 1B-1B-1, *Flight Manual*, 1 September 2014 (Change 7: 15 February 2022)
(5) 1B-1B-2-70JG-30-1, *Propulsion-Ground Operation*, 15 April 2022
(6) 1B-1B-2-70JG-40-1, *Propulsion Engine Testing*, 15 Feb 2022
(7) 1B-1B-2-72JG-70-1, *Engine Exhaust*, 1 Feb 2022 (Change 1: 01 April 2022)

SWITZER.TOBIAS.B. Digitally signed by SWITZER.TOBIAS.B.

9 December 2022

TOBIAS B. SWITZER, Colonel, USAF
President, Accident Investigation Board

STATEMENT OF OPINION

B-1B Lancer, T/N 85-0089
DYESS AFB, TX
20 APRIL 2022

Under 10 U.S.C. § 2254(d) the opinion of the accident investigator as to the cause of, or the factors contributing to, the accident set forth in the accident investigation report, if any, may not be considered as evidence in any civil or criminal proceeding arising from the accident, nor may such information be considered an admission of liability of the United States or by any person referred to in those conclusions or statements.

1. OPINION SUMMARY

On 20 April 2022, at approximately 2216 local time (L), the Mishap Aircraft (MA), a USAF B-1B, tail number 85-0089, experienced a catastrophic engine failure and fire on the #1 engine while undergoing maintenance on the main ramp at Dyess AFB, Texas. The MA suffered catastrophic damage to the #1 engine, as well as extensive fire damage to the left nacelle and wing. Debris from the explosion struck one Airmen who suffered minor injuries and was treated promptly at the local hospital. The estimated cost of damage sustained by the MA is $14,943,680.00.

2. CAUSES

I find by a preponderance of the evidence that high cycle fatigue on the #1 engine's 2nd Stage Fan Disk was the cause of the accident. High cycle fatigue is a low-stress event that causes an engine component to deform within its elastic range during engine acceleration and return to its original form when the engine decelerates. High cycle fatigue occurs due to the heating and cooling of the component during engine acceleration and deceleration and was accounted for during the design of the engine and its components. Laboratory testing demonstrated that a crack began on the surface of the 2nd Stage Fan Disk at the corner of a blade slot and the forward face of the disk. The crack, once initiated by the stress induced from repeated acceleration and deceleration of the engine, was propagated by a mix of high cycle and low cycle fatigue. Low cycle fatigue is a high-stress event that exceeds the elastic strength of the material, causing permanent deformation and leading to component failure within a few engine cycles. The crack and its initial growth increased the stress beyond the 2nd Stage Fan Disk's elastic strength, which left it susceptible to low cycle fatigue. The surface crack grew to a depth of approximately 0.7 inches before the 2nd Stage Fan Disk broke apart, causing the #1 engine to fail catastrophically. The source of the high cycle fatigue that caused the initial crack in the 2nd Stage Fan Disk could not be determined.

3. SUBSTANTIALLY CONTRIBUTING FACTOR

No factors substantially contributed to this mishap.

4. CONCLUSION

Following analysis of available data, review of the B-1B System Program Office analysis, witness testimony, engineering analysis, Air Force technical orders, regulations, and guidance, I find by a preponderance of the evidence that the cause of the accident was high cycle fatigue of an unknown source on the MA's #1 engine 2nd Stage Fan Disk. No factors substantially contributed to this mishap.

SWITZER.TOBIAS.B. Digitally signed by SWITZER.TOBIAS.B.

9 December 2022

TOBIAS B. SWITZER, Colonel, USAF
President, Accident Investigation Board

INDEX OF TABS